International Cartographic Association
Association Cartographique Internationale

Using physiological measurement to investigate fear in virtual geographical spaces

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Keywords: electrodermal activity, physiological responses, geovisualization, virtual reality, fear

Abstract:

Fear-inducing environments arise from various safety concerns within public spaces, including static elements such as inadequate lighting and dynamic factors like overcrowding and social biases (Kelling and Wilson, 1982; LaGrange et al., 1992; Sampson and Groves, 1989). Identifying elements that evoke fear is essential for urban planning, as this enables the development of strategies to create safer and more inclusive public spaces. Virtual reality (VR) offers a promising platform for identifying and mitigating such stressors in urban planning contexts. Studies indicate that immersive VR using head-mounted displays (HMDs) enhances both presence and emotional engagement compared to non-immersive platforms, e.g., desktop visualizations (Bouchard et al., 2017; Cummings and Bailenson, 2016; Felnhofer et al., 2015). This makes VR particularly effective for investigating negative emotional states, such as fear, and the spatial features eliciting these emotional states.

Explicit methods, such as surveys, can be used to identify fear-inducing factors; however, individuals may not always be consciously aware that certain elements trigger feelings of fear (Schlosser and Zeile, 2018). Additionally, interindividual differences may not be adequately accounted for in such approaches. In contrast to explicit methods, physiological measurements have the advantage of capturing implicit emotional reactions (Felnhofer et al., 2015). Techniques such as measurement of skin conductance, skin temperature, and heart rate monitoring (Braithwaite et al., 2015) have become increasingly accessible through affordable devices like electrodermal activity (EDA) wristbands. Moreover, EDA is widely recognized as a reliable indicator of physiological responses associated with stress and fear (Faghih et al., 2015; Reinhardt et al., 2012).

In this study, a virtual geographic "space of fear" was modeled after a real-world location, incorporating visual and auditory stimuli. Topographical variations and relevant geographical features were carefully integrated to preserve spatial accuracy, enabling more realistic transfer of findings to urban planning applications. The experiment consisted of three scenarios: a baseline daytime scene and two nighttime scenes differing only in lighting configurations. In one nighttime scenario, no additional lighting was provided, whereas the other included two strategically placed spotlights (Figure 1).

Figure 1. The self-built urban green space represented as a virtual 3D environment a) top view b) daytime scene c) nighttime scene with additional lightning

Fear-inducing auditory and visual stimuli were presented exclusively in the nighttime scenarios. The experimental framework was adapted from Keil et al. (2023), which utilized VR-capable urban models. Participants experienced the environments using a Valve Index HMD and wore an Empatica E4 wristband to measure EDA. Although more

https://doi.org/10.5194/ica-abs-10-237-2025

individuals participated, only the data from 37 participants (17 females, 20 males) met the quality criteria and were included in the final analysis. Initial results from the ongoing analysis of the physiological data can be presented. At first, we aimed to ensure that it is possible to detect skin conductance reactions to different stimuli representing a fear response. Based on Benedek and Kaernbach (2010), the response time after a stimulus occurs within five to ten seconds. Therefore, we selected timeframes of eight seconds before and after the stimuli and compared them. Significant differences were observed in the aggregated mean EDA levels pre- and post-stimuli ($t(36) = -3.71$, $p = .001$, $n = 37$). The statistical analysis indicates that it is possible to detect reactions to different stimuli that represent a fear response.

The next step is to compare the reactions to the auditory stimuli between the two lighting settings to confirm the effectiveness of adaptable lighting fixtures reducing fear responses based on the physiological measurements. First results indicate various differences in skin conductance responses in the different conditions. These findings demonstrate how spatially grounded VR simulations can serve as proxy environments for testing urban design interventions—such as lighting—before real-world implementation, allowing planners to evaluate emotional and related physiological responses to specific configurations. Ultimately, these implicit methods have the potential to assist urban planners in identifying previously overlooked fear-inducing elements and in testing effective solutions within a virtual environment, thereby streamlining their integration into the planning process.

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